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Efficient Filtering Methodologies for Finite-Difference-Based Global Climate Models on Massively Parallel Systems

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The meridional convergence of meshpoints at the north and south poles presents a major challenge for latitude/longitude grid-based finite-difference global climate models. These codes, which generally use an explicit difference algorithm, require a very small timestep in the neighborhood of the poles for numerical stability. A procedure, originally developed by Arakawa, is to use a timestep that violates the stability condition in the polar regions and to then apply zonal filters at the higher latitudes. Although this approach is superior to that of using a small timestep everywhere, it does not scale well with increasing mesh size. This is because of the poor scaling of the time required to compute a transform as well as the fact that in the neighborhood of the poles. the maximum allowable timestep for stability is effectively quadratic as the mesh is refined. At 1 -degree (latitude) by 1 l/4-degree (longitude) resolution calculations have been known to spend close to three quarters of their time computing filters.

A further difficulty occurs when applying these filters in parallel codes that utilize a latitude/longitude domain decomposition message passing approach. Those processors responsible for the equatorial subdomains will be idle while those responsible for the polar regions will be completely occupied.

We report progress on several fronts. We have developed approximations to the Arakawa filters that have smooth transfer functions and limited longitudinal extent. These finite-width filters appear to give answers that are in agreement with the original global filters. at much reduced computation time. Second, we have developed a redistribution procedure that allows all computational processors to contribute to the faltering computation. This methodology has been applied quite successfully in our ocean code and is presently being implemented in the atmospheric model. Basic to this procedure is the assignment of latitude/depth (or latitude/height) lines to the various processing elements. This strategy facilitates the implementation of Fast Fourier Transforms as a further approach toward streamlining the filter computation in the atmospheric model.

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